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(19)

(54) APPARATUS AND METHOD FOR BENDING ELONGATED OBJECTS

(71) We, COJAFEX N.V., a company organized under the laws of the Netherlands of Glashaven 10c, Rotterdam, Holland, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in the following statement:—

The invention relates to continuously and progressively bending elongated objects, particularly tubes, but also for example rods or beams, and particularly to apparatus and a method by which the object is subjected to a longitudinal force urging the object, guided by guide means such as rollers, progressively through a heating means, heating the object in a narrow transverse zone, so as to lower in said zone the limits of elasticity and of stretching strain. the object beyond the heating means being guided into a bend by means of a bending arm to which the object is fastened in such a manner as to be unable to rotate, said arm having its centre of rotation substantially in the plane of the heated zone.

Such an apparatus for bending metal tubes is known from Czecho-Slovakian Patent Specification 111,259.

Bending takes place in the narrow heated zone, and as in this zone the bending moment is consequential to the force exerted on the tube in longitudinal direction thereof, stretching at the outer side of the bend is decreased and deforming at the inner side of the bend is increased, so that at the outer side of the bend the wall thickness is reduced to a lesser extent than when no such longitudinal force is exerted on the tube.

However experience has taught that under some circumstances, in particular when heavy tubes are being bent, the apparatus is subjected to excessively high loads which are difficult to cope with and which may lead to breakdown of the machine. Furthermore a transverse force is set up in the heated zone of the tube, which force may lead to undesired deformations of the tube in the heated zone. The above high loads to which the apparatus is subjected are to a great extent a consequence of a very large bending moment occurring at the place where the tube is fastened to the bending arm by clamping or otherwise, and of the large force exerted on the tube by a guiding roller situated near the heated zone.

It is an object of the invention to remedy the above drawbacks of the known apparatus.

According to the invention we provide apparatus for bending an elongated object in which a longitudinal force is applied to push the object progressively past guide means and through means for heating the object in a narrow transverse zone and an arm is firmly fixed to the object beyond said zone and is mounted to rotate about a centre of bending curvature which centre lies substantially in a transverse plane passing through said zone at a distance from said zone which, for a given bending curvature, is variable during the bending operation.

We further provide a method of bending an elongated object using the aforesaid apparatus according to the invention, in which the bending process is controlled by shifting the heating means along the object to be bent in dependence on a deviation in the distance between the pivot point of the bending arm and the heated zone of the object, so as to correct a deviation of the radius over which the object is to be bent.

According to an embodiment of the invention, the said said centre of bending curvature is mounted in such a way that it can move during the bending operation in a direction perpendicular to the longitudinal axis of the unbent portion of the

object, the guide means being arranged to guide the unbent portion of the object along a fixed path.

According to another embodiment of the invention, said centre of bending curvature is fixed for a given curvature and the guide means is mounted in such a way that the heating zone can move during the bending operation toward or away from said centre.

With all embodiments the plane of the narrow zone of heating should still pass substantially through the centre of bending curvature, notwithstanding movements of the tube or the like.

It is to be understood that in both the abovementioned embodiments the movements of the centre of the bending arm or of the heated zone of the tube or the like towards each other or away from each other during the bending process will only be relatively small; the actual movements of these parts may be further reduced by inserting resilient means in their mountings.

It has been shown in practice that with both arrangements drawbacks due to excessive loads on the bending machine as well as on the tube or like object are completely or substantially completely prevented, even if heavy tubes are being bent. Thus the advantages of the present invention reside in obtaining a bent article without undesired deformations as well as in the possibility of employing machines of lighter construction.

The desired mobility of either the centre of rotation of the bending arm or of the heated zone of the elongated member may be accomplished in a number of ways. Thus in the case of a movable bending arm centre, the bending arm may for example be connected at its centre of rotation pivotally to a rocking arm or coupling rod extending substantially parallel to the unbent portion of the elongated object, or to a slide movable substantially perpendicularly to the unbent portion of the elongated object.

As has been said above resilient means may be provided to counteract to a certain extent the displacement of the bending arm's centre of rotation or the guiding means for the tube or other elongated object or member. Such resilient means may be formed for instance by springs or rubber blocks.

The possibility of a relative movement between the bending arm's centre of rotation and the guiding means for the unbent portion of the elongated member, present in a machine according to the invention, opens the way to a special method for effecting or controlling the bending process.

It has been found that a small deviation in the radius over which the member is to be bent causes a small displacement of either the bending arm's centre of rotation or of the member guiding means, and that such deviation can be corrected by a small displacement of the zone heating means in the direction of the longitudinal axis of the unbent member. Such a correction can be effected manually or automatically in dependence on a displacement as mentioned above.

The invention will now be further elucidated by the description of some examples of machines embodying the invention, reference being made to the accompanying drawing on which such machines are shown diagrammatically, as far as necessary for the understanding of the invention.

Fig. 1 shows a top view of a first example of a bending machine according to the invention:

Fig. 2 shows a detail thereof in modified form.

Figs. 3 - 6 show in a very diagrammatic way how the principle on which the invention is based can be applied to bending machines, having a fixed centre of rotation of the bending arm.

Fig. 7 shows a top view of an example of a bending machine according to the invention, constructed along the lines indicated in Fig. 6.

Fig. 1 shows a tube bending machine with a bending arm, the centre of rotation which is movable.

In this Figure the tube 1 to be bent is located in the machine, the base frame of which is indicated by the reference numeral 2, and is guided during its forward movement, caused by a force acting thereon in the direction of the arrow 3 (by means not shown in the drawing), by guide means comprising rollers 4 and 5, connected to the frame 2 and further guided by guiding member 6. This latter member can comprise a collar piece, fixed to the tube and having rollers 7 running along guide faces 8 of the frame 2.

The forward end of the tube is firmly fixed to the bending arm 10, e.g. by means of a clamping device 9. The bending arm is rotatably connected to a rocking arm or coupling rod 12 by means of a journal at 11, the rocking arm itself being pivotally connected to the frame 2 by means of a journal 13.

Beyond the rollers 4, 5 the tube is encircled by a heating device 14, adapted to heat at this place a narrow zone of the tube to a temperature required for the bending of the tube. Substantially within a transverse plane passing through said zone the centre of rotation 11 of the bending arm 10 is situated, which is essential for satisfactory operation of the machine. The heating device 14 is preferably of the elec-

tric inductor type but may be of different construction, e.g. adapted for heating by gas. It is essential however that only a narrow zone of the tube will be heated thereby.

The operation of the machine is as follows.

With heating by 14 operative the tube is moved forward in the direction of the arrow 3, the force required for said movement being supplied e.g. by a motor driven screw spindle or a hydraulic cylinder. That end of the tube which is fixed at 9 to the bending arm can only move about the centre of rotation 11 of the bending arm 10, which causes at the place heated by 14 a bending with a radius equal to the distance between the centre 11 and the centreline of the unbent portion of the tube. In order to prevent deformation in that part of the tube which has just passed the heating device 14 the tube, particularly when it is a thin-walled tube, will if necessary be cooled directly beyond the heated zone, e.g. by spraying water thereon.

It should be noted that during the bending operation, the side force acting on the rolelr 5 will only be small. In the heated zone of the tube the transverse or shearing force has a negligible value, so that it will not give rise to undesirable deformations. The cold and therefore rigid tube sections adjacent to the heated zone tend to keep up the original round sectional shape in the heated zone; thus it is unnecessary to fill the tube with sand or a mandrel. Further the compressive force working in the heated zone will counteract wall thinning at the outer side of the bend.

Ideally the centre of rotation 11 of the bending arm 10 should stay at exactly the same place during the bending process, and also the radius of the bend should be kept constant.

By disturbances of secondary nature, however, e.g. irregularities on the wall thickness, a deviation can arise in the bend radius, which deviation is accompanied by a slight displacement of the centre of rotation 11 in a direction towards or away from the guide means (to the right or the left in Fig. 1). According to the invention this phenomenon is made use of to effect a correction. It is apparent that by slightly shifting the heating device 14 in the longitudinal direction of the tube the bend radius is modified in length. The method of correction according to the invention consists in measuring in an arbitrary way the displacement of the centre of rotation 11, and shifting the heating device in dependence on the measured value until the centre 11 again takes up its original position. Such method can be performed by the attendant of the machine but can also be performed automatically. In the latter case a sensing device, responsive to a displacement of the said centre of rotation or of the guide means, may e.g. give a signal, which causes a mechanism to operate, via a transmission (electric, pneumatic, etc), to shift the heating device.

To the same end an equivalent to shifting the heating device would be shifting of the centre of rotation 11 of the bending arm 10 in a direction parallel to the unbent position of the member to be bent.

The machine diagrammatically shown in Figure 1 is arranged for adaptation to different tube diameters and radius of bending by adjustment or exchange of the rollers 4, 5 of the guide shoe 6, of the fixing member 9 and by change of the effective length of the bending arm 10. An example of means to attain the latter is shown in Figure 1 by the guide slots 15 and 16, in which slots the centre of rotation 13 of the rocking arm 12 and the fixing member 9 can be set tight.

The machine can be arranged for bending tubes or other elongated objects in a helical shape by displacing during the bending process the centre of rotation 13 gradually in a direction perpendicular to the plane of drawing of Figure 1.

The movability of the centre of rotation 11, can, as has already been said, be attained in other ways than by means of the rocking arm 12, e.g. by means of a slide movable along guides, by means of a straight motion mechanism, or as indicated in Figure 2, by means of flexible strips or blade springs 17, which act as a pivot-holding clip.

Prevention of a permanent transverse force on the centre of rotation of the bending arm can also be attained, when a slide is provided to which the arm is pivotally connected, by adjusting the position of the slide by means of a mechanism controlled by such a temporarily occuring force until said force is cancelled or nearly so. The force concerned may be determined at the centre of rotation itself or at roller 5.

In the Figs. 3, 4, 5 and 6 there is shown in a very diagrammatic way how the principle on which the invention is based can be applied in bending machines in which (for a given bending radius) the centre of rotation of the bending arm has a fixed position with regard to the base of the bending machine.

In these Figures the reference numeral 101 indicates the stationery centre of rotation of the bending arm 102, which at 108 is in a rotation free manner connected to tube 103 (or other elongated object) to be bent, e.g. by means of a clamping member.

The distance 101 - 108 is of course equal to the radius over which the object is to be

bent; in these Figures bending has taken place already over some length of the object. The bending arm 102 and the bent portion of the tube constitute a rigid assembly, providing the theoretical lever of length r, which constantly remains perpendicular to the longitudinal axis of the object to be bent. The tube 103 (by which designation any elongated object to be bent is indicated hereinafter) is guided over its unbent portion in a guide frame or support 104, with interposed guide rollers 106 and 107, transmitting transverse forces from the tube to the guide frame. A longitudinal force is applied to the tube by means of a power device operating on the tube on one hand and on the guide frame on the other hand. In the Figures the power device is symbolically sketched as a spring 105, but in practice it may consist of a hydraulic or pneumatic cylinder, a motor driven screw-spindle or screw rack or the like.

At the place indicated at 109 the tube is locally heated in the plane, indicated by a dotted line, passing substantially through the centre of rotation 101 of the bending arm. Driven forward by the longitudinally acting force the tube is bent over the radius r in the heated zone through which the tube is gradually displaced.

According to the invention measures have been taken to allow the guide frame or support 104 to move at its forward end, bearing the heating device, to some extent towards the centre of rotation 101 of the bending arm or away from it, in order to suppress wholly or partly the shearing force in the heated zone and to reduce the load on the bending arm and its centre of rotation.

In the sketch of Fig. 3 the guide frame 104, in order to attain the movability as mentioned above, is provided at its forward end with sideways extending guide rails or bars 110, adapted to slide between guide rollers 111 with stationary axes.

Instead thereof the guide frame may bear rollers adapted to move between stationary rails, or guiding surfaces may be applied instead of rollers.

The sketches of Figures 4, 5 and 6 show in a diagrammatic way arrangements in which a sideways displacement as obtained with the arrangement of Fig. 3 is at least approximated.

Thus in Fig. 4 the guide frame 104 has pivotally connected to it at the points 114, 115 respectively two short coupling rods or tie rods 112 and 113, the other ends of said rods being pivotally connected at 116 and 117 respectively to stationary points.

In Fig. 5 the rear end of the guide frame is adapted to pivot about the fixed point 118.

In Fig. 6 the guide frame 104 has pivotally connected to it at 120 one tie rod, the other end of which pivots about a fixed point 122, whereas the rear end of the guide frame is provided with a slot 124 adapted to slide along a stationary pin or roller 123.

It will be appreciated that the same object can be achieved with other combinations.

Fig. 7 shows in more detail a machine according to the principle of Fig. 6 as seen from above.

The numeral 125 indicates in diagrammatic way the base frame on which the various parts are mounted, such as the journal 101 constituting the centre of rotation of the bending arm 102, and the pin 123, cooperating with the slot 124 of the guide frame 104. The tube 103, here shown in a position in which bending has not yet been effected, is firmly fixed to the bending arm 102 by means of a clamping member 108 in a rotation-free manner. Adjacent the forward end of the guide frame 104 the tube 103 is guided by guide rollers 106 of the guide frame, whereas at its rear end the tube is enclosed by a shoe or chuck 126 provided with rollers 7 for guiding the rear end of the tube within the frame 104.

The force for moving the tube in a forward direction in the guide frame is supplied by a screw spindle 127, threaded in the rear end of the frame 104, and adapted to be rotated by means of e.g. an electromotor (not shown in the drawing). As already said other devices can be applied for supplying the force required.

At some distance from the forward end of the guide frame 104 a coupling rod 121 generally parallel to the frame is connected thereto by means of the pivot 120; the other end of the rod pivots at 122 about a point fixed with regard to the base frame 125. The connection between the pivot 122 and the base frame 125 is brought about with the aid of two rods 128 and 129, the first adapted to pivot about a point 130 of the base frame, the latter about a point 131 of the base frame. The point 130 is situated about halfway between the points 101 and 123, the point 131 in the neighbourhood of point 101. Whereas the rod 128 has a fixed length, the length of the rod 129 can be altered by means of a turnbuckle 132. The purpose thereof will be described later on.

At its forward end the guide frame 104 supports a device 133 for heating the tube in the narrow zone, indicated by 109, transverse to the longitudinal axis of the unbent tube portion. This device may comprise electrical apparatus for feeding alternating current to an induction ring 134, encircling the tube in the said zone. Other heating appliances may be used provided the tube will be heated thereby in a narrow zone only. The heating device may be combined with means for cooling the progressively

moving tube in the zone which has just been heated.

The plane of the zone 109 and of the heating ring 134 passes substantially through the centre of rotation 101 of the bending arm, or other wise stated: the longitudinal axis of the unbent portion of the tube is substantially perpendicular to the line connecting zone 109 and the centre of rotation of the bending arm. This relation is essential to the proper operation of the machine and should therefore remain when the radius over which a tube is to be bent is altered.

When the radius of bending is to be altered the effective length of the bending arm 102 as well as the position of the guide frame 104 with regard to the base frame 125 is modified.

A modification of the length of the bending arm 102 is effected by displacing the clamping block 108 along the arm, the latter being provided with a slot 135, in which the block 108 can be fixed at the place desired. A modification of the position of the guide frame, fitting the first-mentioned modification, is obtained by altering the length of the rod 129; thereby the rod 128 pivots about the centre of rotation 30, whereas the slot 124 slides along the pin 123. The location of the points 130 and 124 and the length of the rod 128 are chosen such that with any selected bending radius the right angle between the longitudinal axis of the unbent tube portion and the line connecting 109 and 101 is practically maintained.

During the bending process small deviations of the desired bending radius may occur due to incidental causes such as variations in homogeneity of the tube material. Such deviations manifest themselves in a slight rotation of the guide frame 104 about the point 123 and a corresponding rotation of the rod 121 about the fixed point 122. Such a deviation can be corrected by a suitable shifting of small extent of the zone 109 in the longitudinal direction of the unbent tube portion. Thus when a rotation of the tie rod 121 is observed a suitable shifting of the zone 109 can be accomplished by adjusting the position of the heating device 133, 134 with regard to the forward end of the guide frame, which can be done either by hand or automatically. In the latter case a sensing device can be applied which upon e.g. a rotation of the rod 121 delivers a signal causing a displacement of the heating device by electric, pneumatic or hydraulic means.

Application of the present invention is not limited to the embodiments described. For example, the construction shown in Fig. 7 can be modified in such a way that the pivot 120 and the slot 124 of the guide frame 104 are located in an axial plane of the guide frame at right angles to the one depicted. Another possible modification of the machine of Fig. 7 would be to mount the guide rollers 106 and the heating device 133, 134 not on the guide frame 104, but on a separate auxiliary support, slidably arranged in the guide frame and connected to the base frame 125 by means of rods similar to the rods 121 and 128 of Fig. 7. With such construction the guide frame 104 needs to be shifted lengthwise upon altering the bending radius, so that the shot-and-pin guiding means 123, 124 at the rear end of the guide frame can be replaced by a pivot, such as the pivot 118 in Fig. 5.

In order to increase the compressive force in the heated zone, so as to counteract wall thinning in the outer side of the bend, an additional braking force can be applied to the bending arm; on the other hand it may prove desirable, e.g. with thin-walled tubes and very plastic materials, to apply to the bending arm an additional driving force. For both purposes an electric or hydraulic motor with driving as well as braking properties can be used.

The invention has been explained in the above mainly in connection with the bending of round-section tubes, such as steel tubes. It will be understood that according to the invention machines can be built for bending other elongated members, such as rods, rails and beams. The material of these members need not be metal, but may be another thermoplastic material, such as an artificial thermoplastic polymer or glass. The method of heating should of course be in accordance with the nature of the material to be bent. Instead of heating by electric inductance, only applicable with electrically conductive materials, heating by a source of radiation, by hot air or by gas can find employment under suitable conditions.

WHAT WE CLAIM IS:—

1. Apparatus for bending an elongated object in which a longitudinal force is applied to push the object progressively past guide means and through means for heating the object in a narrow transverse zone and an arm is firmly fixed to the object beyond said zone and is mounted to rotate about a centre of bending curvature which centre lies substantially in a transverse plane passing through said zone at a distance from said zone which, for a given bending curvature, is variable during the bending operation.

2. Apparatus according to claim 1, in which said centre is mounted in such a way that it can move during the bending operation in a direction perpendicular to the longitudinal axis of the unbent portion of

the object, the guide means being arranged to guide the unbent portion of the object in a fixed track.

3. Apparatus according to claim 1, in which said centre is fixed for a given curvature and the guide means is mounted in such a way that the heating zone can move during the bending operation toward or away from said centre.

4. Apparatus according to claim 2, in which the arm is pivotally connected to a rocking arm extending from a pivot in a direction substantially parallel to the guide track for the unbent portion of the object.

5. Apparatus according to claim 2, in which the arm is pivotally connected to a slide member adapted to move in a direction perpendicular to the guide track for the unbent portion of the object.

6. Apparatus according to claim 5, in which the slide member is connected to means adapted to move the slide member in dependence on a side force acting on the pivot of the arm.

7. Apparatus according to claim 1 or 2, in which means are provided for resiliently counteracting a change in the distance between said centre and said zone.

8. Apparatus according to claim 7, in which the bending arm centre pivot is resiliently mounted in the apparatus.

9. Apparatus according to claim 3, in which the guide means includes a longitudinal guide frame on which the heating means is supported and which is tied to a base frame of the apparatus so as to be displaceable in a direction substantially perpendicular to the length of the guide frame.

10. Apparatus according to claim 9, in which the end of the guide frame adjacent the heating means is provided with a straight motion mechanism.

11. Apparatus according to claim 9, in which the end of the guide frame adjacent the heating means is tied to the base of the apparatus by means of one or more coupling rods, each having one end pivotally connected to the base frame of the apparatus and having the other end pivotally connected to the guide frame.

12. Apparatus according to claim 11, in which the effective length of the bending arm is adjustable and the position of the guide frame for the unbent portion of the elongated object can be adjusted to meet the adjustment of the bending arm length.

13. Apparatus according to claim 12, in which the effective length of the bending arm can be adjusted by displacing the means by which the object to be bent is fixed to the bending arm, along said arm, while displacing the pivot or pivots connecting said rod or rods with the base, the guide frame being connected, at the end thereof remote from the heating zone, to the base frame by means allowing both a rotation of the guide frame as well as a displacement of the guide frame in its longitudinal direction.

14. Apparatus according to claim 13, in which said connecting pivot is arranged at the end of a further rod the other end of which is pivotally connected to a point of the base frame situated between the pivot point of the bending arm and the point where the guide frame is connected to the base frame.

15. Apparatus according to claim 14, in which the end of said further rod connected to the coupling rod is also connected to the base frame by means of another rod, of adjustable length.

16. Method of bending an elongated object using an apparatus according to any of the preceding claims, in which the bending process is controlled by shifting the heating means along the object to be bent in dependence on a deviation in the distance between the pivot point of the bending arm and the heated zone of the object, so as to correct a deviation of the radius over which the object is to be bent.

17. Apparatus according to claim 2 for carrying out the method of claim 16, in which a sensing means for detecting a displacement of the pivot point of the bending arm is operatively connected to means for shifting the heating means.

18. Apparatus according to claim 3, for carrying out the method of claim 16, in which a sensing means for detecting a deviation in the position of the guide means for the unbent portion of the object to be bent is operatively connected to means for shifting the heating means.

19. Apparatus according to claim 1, substantially as described with reference to the accompanying drawings.

20. Method of bending an elongated object by means of apparatus according to any of claims 1 to 15 and 19.

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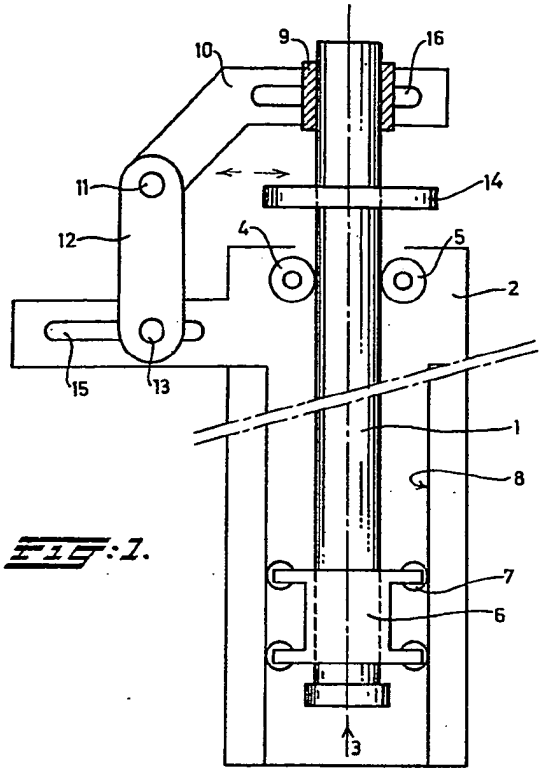

FIG. 1.

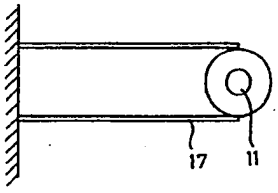

FIG. 2.

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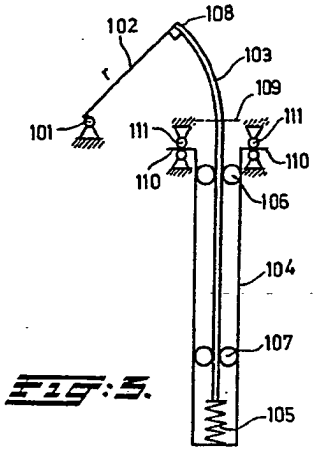


FIG: 5.

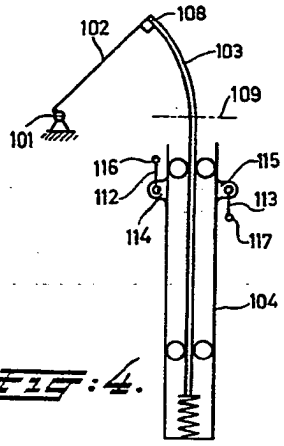
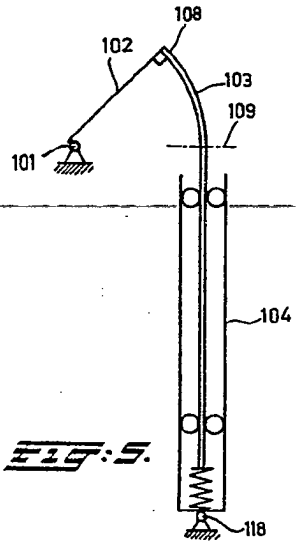


FIG: 4.



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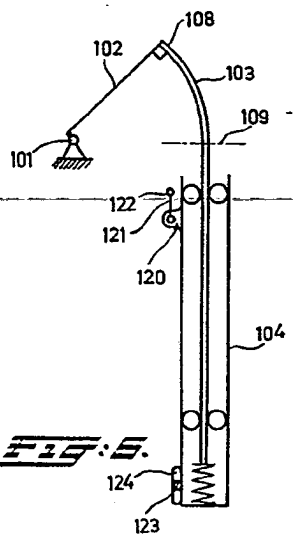
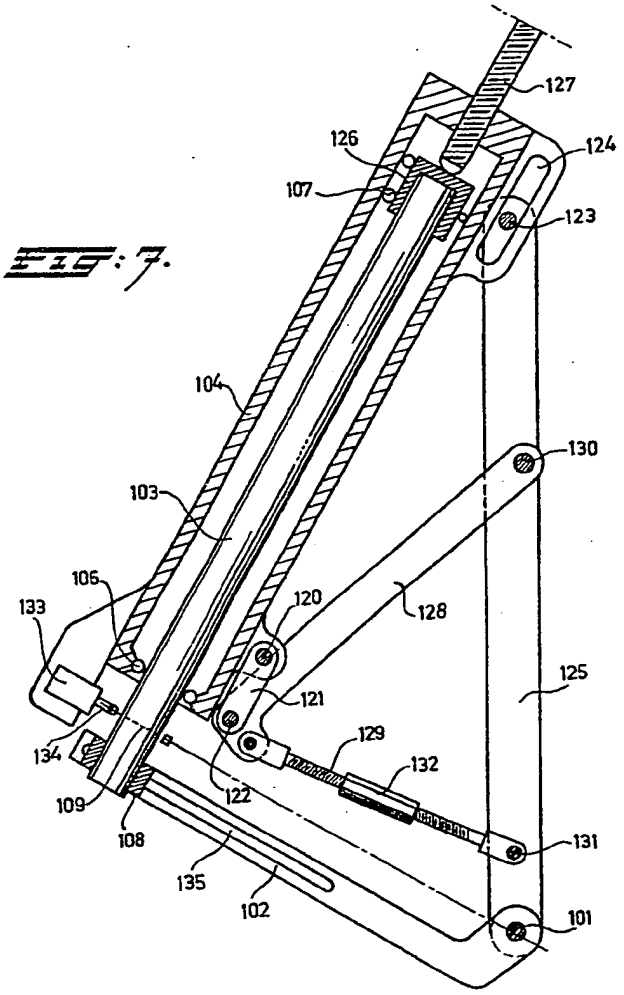


FIG: 5.

Fig. 7.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